$PV = mRT \qquad C_p = C_v + R \qquad Z = \frac{Pv}{RT} = \frac{v_{actual}}{v_{ideal}}$

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \qquad T_R = \frac{T}{T_{cr}} \quad P_R = \frac{P}{P_{cr}} \quad v_R = \frac{v_{actual}}{RT_{cr}/P_{cr}}$

$x = \frac{m_{vapor}}{m_{total}} \qquad y = y_f + xy_{fg} \qquad T(K) = T(°C) + 273$

$$\underbrace{E_{in} - E_{out}}_{\text{Net energy transfer by heat, work, and mass}} = \underbrace{\Delta E_{system}}_{\text{Change in internal, kinetic, potential, etc., energies}} \quad \text{(kJ)}$$

$\Delta E = \Delta U + \Delta KE + \Delta PE$

$\Delta U = m(u_2 - u_1) \qquad \Delta KE = \frac{1}{2}m(V_2^2 - V_1^2)$

$\Delta PE = mg(z_2 - z_1)$

(1) General $\qquad W_b = \int_1^2 P\,dV$

(2) Isobaric process

$W_b = P_0(V_2 - V_1) \quad (P_1 = P_2 = P_0 = \text{constant})$

(3) Polytropic process

$W_b = \frac{P_2V_2 - P_1V_1}{1 - n} \quad (n \neq 1) \quad (PV^n = \text{constant})$

(4) Isothernal process of an ideal gas

$W_b = P_1V_1 \ln\frac{V_2}{V_1} = mRT_0 \ln\frac{V_2}{V_1} \quad (PV = mRT_0 = \text{constant})$

$W_{sh} = 2\pi n T \qquad W_e = VI\,\Delta t$

$W_{spring} = \frac{1}{2}k_s(x_2^2 - x_1^2) \qquad W = W_{other} + W_b$

For ideal gases

$\Delta u = u_2 - u_1 = \int_1^2 C_v(T)\,dT \cong C_{v,av}(T_2 - T_1)$

$\Delta h = h_2 - h_1 = \int_1^2 C_p(T)\,dT \cong C_{p,av}(T_2 - T_1)$

For *incompressible substances*

$\Delta u = \int_1^2 C(T)\,dT \cong C_{av}(T_2 - T_1)$

$\Delta h = \Delta u + v\,\Delta P$

$\sum \dot{m}_i = \sum \dot{m}_e \quad \text{(kg/s)} \qquad T(K) = T(°C) + 273$

$$\dot{Q} - \dot{W} = \sum \underbrace{\dot{m}_e\left(h_e + \frac{V_e^2}{2} + gz_e\right)}_{\text{for each exit}} - \sum \underbrace{\dot{m}_i\left(h_i + \frac{V_i^2}{2} + gz_i\right)}_{\text{for each inlet}}$$

$$\frac{1}{v_1}V_1A_1 = \frac{1}{v_2}V_2A_2 \qquad \theta = h + ke + pe = h + \frac{V^2}{2} + gz$$

$$\eta_{th} = \frac{W_{net,\,out}}{Q_H} = 1 - \frac{Q_L}{Q_H} \qquad \eta_{th,\,rev} = 1 - \frac{T_L}{T_H}$$

$$COP_R = \frac{Q_L}{W_{net,\,in}} = \frac{1}{Q_H/Q_L - 1} \qquad COP_{R,\,rev} = \frac{1}{T_H/T_L - 1}$$

$$COP_{HP} = \frac{Q_H}{W_{net,\,in}} = \frac{1}{1 - Q_L/Q_H} \qquad COP_{HP,\,rev} = \frac{1}{1 - T_L/T_H}$$